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Abstract: Few women and minorities work in STEM areas, making urgent appropriate role models, cultural barrier education, and growth mindset development. This study focused on a diverse group of 24 fifth grade girls at an urban school learning about successful mathematical careers of contemporary women of different races. Students viewed illustrated slide shows of the women's lives and accomplishments, discussing their jobs and barriers they overcame. Students gained spatial skills constructing dioramas of the women's lives and careers. Thematic analysis of student responses to questionnaires and sentences from reflection essays revealed aspects of a mathematician's life and work that allowed students to feel inspiration or connection: concern for others and equity; professional trailblazer; persistence; mathematics passion; social life; and outside interests.

Keywords: elementary students, gender equity, images of mathematicians, mathematics careers, spatial thinking

Introduction

The United States needs to increase its production of highly-educated workers in the STEM (Science Technology Engineering and Mathematics) fields to continue to compete in the global marketplace (National Science Foundation, 2006). Other industrialized nations award a greater percentage of bachelor's degrees in life science, physical sciences, mathematics, computer sciences, and engineering (National Center for Education Statistics, 2007). The National Science Foundation (2008) projects that growth in STEM jobs will outpace other areas.

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Although, during their K-12 education years, both boys and girls study mathematics and science in approximately equal numbers with equal achievement and are similarly prepared for science and engineering majors in college (Shettle et al., 2007), fewer women pursue these majors (National Science Foundation, 2009). Men outnumber women in almost all science and engineering fields at college graduation with women earning only a fifth of the degrees in physics, engineering, and computer science (National Science Foundation, 2008, Table 11).

Female students of all races declare college majors in mathematics in about a fourth of the frequency as males, but Native Americans of both sexes choose math less frequently while Asian Americans of both sexes choose math more frequently with females still at about a quarter of the frequency of males (National Science Foundation, 2014, Table 2-8). These data indicate the need for females of all races to receive appropriate instruction and encouragement to pursue mathematics. The current research project examines the reactions, connections, and attitudes of twenty-four diverse fifth grade girls to an extended project in which they learned about six racially diverse successful women mathematicians and created dioramas of their work and lives. The purpose of the study was to determine from student reflections throughout the project the aspects of a mathematician's life or career that allowed students to feel inspired or connected to mathematics.

Literature Review

Images of Mathematicians

Several people investigated people's mental representations of mathematicians during the 1990's and early twenty-first century (e.g., Ernest, 1996; Howson & Kahane, 1990; Lim, 2002; Picker & Berry, 2000, 2001; Rensaa, 2006). These researchers described the widespread public

image of mathematics as a difficult, cold, abstract, largely-masculine subject. A drawing task similar to the Draw-A-Scientist- Test (Chambers, 1983), in which 215 elementary and middle school students were asked to draw a mathematician at work was administered by researchers to uncover children's images of mathematicians (Picker & Berry 2000). The results were very similar to those obtained for over fifty years from the Draw-A-Scientist-Test (Finson, 2002) in that a stereotyped, middle aged, balding, or wild-haired man was most frequently drawn. When asked to draw an image of a mathematics teacher, children produced images of middle-aged males with eyeglasses, beards, bald heads or weird hair working at the blackboard or on a computer (Picker & Berry, 2001).

Earlier researchers had found that the public image of mathematicians focused on mathematicians as arrogant, elitist, middle class, eccentric males who were social misfits without common sense or sense of humor (Howson & Kahane, 1990). Part of the problem is that the public do not have a clear concept of what mathematicians do in their careers. Children asked to list reasons why someone would hire a mathematician left the response area blank (Picker & Berry). A study in Norway, which involved interviews of adults waiting for flights at an airport (Rensaa, 2006), found that the frequently chosen characteristics of mathematicians were, single, middle-aged, balding men with eyeglasses and outdated clothing, who were unsocial and boring. Participants who held negative views of mathematicians, compared to those who held more neutral or positive opinions, most often identified the work of mathematicians as doing vague calculations. Rensaa (2006) also found interviewees whose own jobs did not require post-secondary education had more negative views of mathematicians. These findings support the idea that a lack of understanding of the diversity of mathematical jobs leads to more negative mental images.

The three key influences on students' perceptions of mathematicians are students' experiences in mathematics classrooms; expectations transferred by parents and significant others; and stereotypes reinforced by media images (FitzSimons, 2002). A study (Mendick, Moreau, & Hollinworth, 2008) conducted in the United Kingdom examined the representations of mathematics and mathematicians in popular culture and their effects on learners. The researchers observed fifty popular films, websites, books, and media programs. They surveyed over five hundred 14-15 year-old students, conducting numerous focus groups and individual interviews, finding images of mathematicians from popular culture are of old, White, middle-class men with rumpled, unstylish clothing, poor posture, and social awkwardness with a single-minded pursuit of mathematical knowledge to the neglect of any social life (Mendick et al., 2008). They also found that mathematics is gendered as male through "the dominant representations of mathematicians being men, the disappearing of women's mathematical contributions and the ways that women doing mathematics are subordinated in a range of ways including their youth and their positioning as appendages to 'greater' male mathematicians" (Sriraman & Steinthorsdottir, 2007; Mendick et al., 2008, p.ii). Another finding of this study was that the representations of male and female mathematicians present their mathematical abilities as natural abilities from birth rather than knowledge and skills acquired through effort, making mathematical ability seem inaccessible to most people. The researchers noted that the image of mathematicians is concerned more with numbers than words, and more with technical rather than emotional matters, making mathematicians unappealing to females.

Based on the study findings just mentioned, the authors (Mendick et al., 2008) recommended that producers of popular culture provide representations of women doing mathematics with more adult women whose abilities are independent of the men in their lives,

and representation of feminine women from different ethnicities, sexualities, ages, social class backgrounds and with different bodies doing mathematics. A recent media example is the movie Hidden Figures (Gigliotti, Chernin, Topping, Williams, Melfi, & Melfi, 2016) featuring African American women mathematicians working for NASA. These authors also suggested that media present a range of ways of engaging with mathematics happily and successfully so that mathematics can be seen as part of someone's life rather than as all consuming. Media images of mathematicians should show the effort expended in learning and doing mathematics rather than portray it as an area for highly gifted individuals with flashes of genius (Mendick et al., 2008). Therefore, the current study emphasized six racially diverse women from different backgrounds who worked hard to learn mathematics and were successful at different interesting jobs while still having a social life and other interests. Living mathematicians were chosen so that students would be able to see what current careers are like and to allow the possibility of communication between the researchers and mathematicians to obtain additional personal information not available from other sources and between students and the mathematicians for a stronger role-model bond. In addition to the previously mentioned recommendations, Mendick and colleagues (2008) suggested that future research examine how other groups of learners view mathematicians, especially elementary students, because this is the time that students develop a relationship with mathematics. Consequently, the current study focused on fifth grade students of ages 10 to 11.

Other researchers in the UK (Evans, Tsatsaroni, & Czarnecka, 2014) studied newspaper advertisements in 1600 editions using a semiotic / discursive approach. They found that advertisers use mathematics to transfer to their products valued characteristics of mathematics like precision, rationality and authority. They found a strong correlation of incidence of

mathematical advertisements with the percentage of middle class readers, and with percentage of male readers, controlling for social class (Evans et al., 2014). They also found that the quality newspapers had less-simplistic advertisements related to mathematics than with a lower socio-economic readership. This indicates the need for students at schools serving low socio-economic populations to be exposed to a more balanced view of mathematics that includes female mathematicians and qualities associated more with femininity such as caring for others.

Reasons for Fewer Females than Males in Mathematics Careers

The American Association of University Women (Hill, Corbett, & St. Rose, 2010) was selected by the National Science Foundation to conduct a study of women's underrepresentation in the STEM fields. Their study, drawing on a large body of research, found that social and environmental factors contribute to the underrepresentation of women in STEM areas. This idea of social-environmental factors is supported by the rapid growth in the number of girls achieving very high scores on standardized mathematics tests once thought to measure innate ability. For example, thirty years ago, only 7% of students scoring above 700 on the SAT math exam at age 13 were female; today 25% are female (Halpern, Benbow, Geary, Gur, Hyde, & Gernsbacher, 2007). This increase in mathematically gifted females illustrates the impact of education on mathematical achievement. Psychological and social influences play a large role in females success in mathematics. For example, girls who are told that their intelligence can expand with practice and experience in mathematics, a growth mindset (Dweck, 2006, 2008), achieve higher scores on math tests and express the desire to continue to study mathematics. A difference in average math performance between girls and boys can no longer be found in the general school population (Hyde, Lindberg, Linn, Ellis, & Williams, 2008). Negative stereotypes about girls' abilities in math still affect girls' test performances, but when girls are told that males and

females are equally capable, both sexes perform similarly. Girls tend to self-assess their math abilities as lower than boys, holding themselves to a very high standard before feeling they are competent enough to succeed in a predominantly male field (Correll, 2001). These attitudes strongly affect girls' aspirations to have mathematics careers.

A significant gender difference in performance between males and females exists in spatial skills, with males consistently outperforming females at all age levels (Voyer, Voyer, & Bryden, 1995). Spatial skills are important because they form a gateway to the STEM fields (Uttal & Cohen, 2012). Experts established in STEM fields may bypass some spatial tasks because they have deep knowledge in the domain. Early in one's study of STEM subjects, spatial skills are needed to solve problems without relying on previous knowledge; spatial skills can help curb dropouts by providing a spatial pathway to understanding difficult concepts (Uttal & Cohen, 2012). Girls' spatial skills can be improved quickly with specific training allowing them the skills and confidence to consider STEM careers (Vasta, Knott, & Gaze, 1996). The need for exercise of spatial thinking prompted the researchers to develop a diorama art project focused on the life and career of each of the six targeted female mathematicians.

The project practiced many spatial thinking skills such as complex three-dimensional construction, painting of color gradients, and balanced arrangement of images. These skills were employed in the construction of a diorama from a cereal box that was cut to open like a book with a cardboard building or structure on the front revealing its interior when the box was opened, pop-out displays inside, and a folded pop-up display on the back with images of the student and the mathematicians accompanied by a reflective essay.

Many people have the bias of thinking that STEM fields are "male" and the arts and humanities are "female" (Heilman, Wallen, Fuchs, & Tamkins, 2004). These biases are often

unconscious and passed on to others, affecting girls' interests in STEM careers. Additionally, people often have negative views of women who aspire to or are employed in "masculine" positions (Heilman, et al., 2004). People tend to judge women to be less competent than men in "male" jobs unless they are visibly successful. Unfortunately, when a woman is noticeably proficient in a "masculine" job, she is considered to be less likable. Because success requires both likability and competence, women in STEM fields can experience a double bind unless they demonstrate strong caring for others to counteract the stereotype (Heilman & Okimoto, 2007).

The large disproportion between the numbers of men and women in science, technology, engineering, and mathematics has often been cited as evidence of biologically-driven gender differences in abilities and interests. Recent improvements in girls' mathematical test scores, however, demonstrate the importance of culture and learning environments in the cultivation of abilities and interests. To diversify the mathematics work force, stereotypes and biases that still pervade our culture and the messages in our classrooms need to be examined. Suggestions for increasing girls' interests in STEM careers (Hill et al., 2010) include:

- Inform girls about girls' and women's achievement in math and science, including the lack of gender differences in performance in most areas.
- Eliminate stereotypes by providing diverse, inclusive, female role models.
- Teach girls, through a growth mindset environment, that new spatial and intellectual skills, such as mathematics, can be acquired.
- Emphasize real-life applications in early STEM courses.

These suggestions were incorporated into the current diverse women mathematicians project by explaining data on girls' achievement on par with boys', discussing barriers that females have faced and how they can be overcome, providing diverse successful female mathematician role

models, modeling a growth mindset, emphasizing that hard work and effort will result in success, and presenting a variety of real-life careers of women in mathematics.

Conceptual Framework

Constructionism. Constructionist theory proposes a robust connection between design – making, building or programming – and learning. Design theorists and learning theorists regard construction of meaning as a core process, bringing these two fields together. Designers focus on what objects mean to them or others and carefully connect an object's features to its context to create a coherent unity (Kafai & Resnick, 2011). The designers' relationships with the objects or situations are the focus of design theory with the final artifact or product being secondary. Learning theorists have begun to examine the role of artifacts in learning. Constructivists like Piaget (Schwebel, & Raph, 1973) and Montessori (Lillyard, 2005; Sobe, 2004) emphasized the importance of manipulation of objects: construction of meaning was enhanced as learners engaged with materials. The more recent theory of Constructionism (*without the "v")* builds on Constructivist theory in that learners build knowledge structures. Constructionism, though, requires that the learner build a public entity – a product for an outside audience – thereby making the project real-world, meaningful, and connected to conversation with others (Ackermann, 2001). "Constructionist learning environments encourage multiple learning styles and multiple representations of knowledge" (Kafai & Resnick, 2011, p.3). Learning explodes as a student continues delving into a topic, making increasing connections (Papert, 2011). In most school situations, the time to construct personal connections to the content is generally absent, but in a Constructionist project, like the dioramas of diverse women mathematicians project

described here, students have multiple opportunities to interact with the content while creating the record of their learning, the dioramas.

Learning by making (a simplified way of talking about constructionism) may break the general education impression that learning is only improved through *better instruction* (Papert & Harel, 1991). Students who are creating constructions are often motivated to understand new concepts, try different methods through experimentation, and seek new information by themselves, rather than waiting for a teacher to instruct them. A study (Harel, 1991) found that children sustained an hour of attention daily for months as they *created* educational software on mathematics topics usually considered boring when students used ready-made software.

Arts Integration. Arts integration into STEM (Science, Technology, Engineering, Mathematics) areas (resulting in "STEAM Education" with the "A" representing the arts) is a relatively recent area of investigation. The arts, including the visual art of diorama-making, have many documented benefits. The arts are considered to be motivating by most students (e.g., Teske, Gray, Klein, & Rule, 2014). Positive dispositions and habits such as creativity, sustained practice, perseverance, and trial and error are taught through the arts (e.g., Gibson, 2003; Hetland, Winner, Veenema, & Sheridan, 2007; Winner, Hetland, Veenema, Sheridan, Palmer, & Locher, 2006; Root-Bernstein & Root-Bernstein, 1999, 2013). Learning in non-art domains is enhanced through arts integration; for example, arts and crafts work assists students in developing observation skills (noticing details while painting or sketching), visual thinking (transforming ideas into symbols or pictures), pattern recognition, and manipulative ability (as they use art tools) (Root-Bernstein & Root-Bernstein, 2013). Spatial thinking, the perception, visualization, and orientation of objects in space, is also enhanced by the arts (Committee on Support for Thinking Spatially, 2006). Spatial skills are important because they are correlated

with entrance to preparation for careers in STEM fields. Spatial thinking skills help novices better understand difficult STEM content before they have attained deep content knowledge (Uttal & Cohen, 2012).

Rationale for Research Project

The current project involving diverse fifth grade students in learning about successful women mathematicians of different races through diorama creation was developed for the following reasons:

1. To assist female elementary students in developing positive attitudes toward mathematics careers through exploration of diverse successful role models, through discussions of myths about female performance in mathematics, through development of a growth mindset in mathematics, and through examination of barriers that women mathematicians have faced along with how they have overcome them.

2. To implement Constructionist theory through students creating dioramas to showcase their learning about women mathematicians, by facilitating discussions of the lives and careers of women mathematicians over most of the school year, via feedback from families, teachers, and peers at the school's multicultural fair, and by reflecting and making connections between the mathematicians and themselves.

3. To use arts integration to motivate students, to support students' spatial skill development important to choosing a mathematics career through a three-dimensional arts and craft project, to foster positive dispositions and habits, and to develop observation, pattern recognition, visual thinking, and manipulative skills.

4. To explore aspects of diverse women mathematicians' careers and lives that attract young people to the career or allow them to feel connected to the person.

Method

Participants and Setting

Twenty-four fifth grade female students (12 White, 9 African American, 2 Hispanic, and 1 Asian) at a low socio-economic public school in the Midwestern United States with 72.8% of the school population receiving free and reduced-cost lunches participated in the study. The racial make-up of the school was 55% White, 34% African American, 9% Hispanic, 1% Native American, and 1% Asian. Approval to conduct the study was obtained from the university, the school district and the building principal. All students and parents provided fully-informed written consent. This population of diverse female youth was ideal for determining how upper elementary girls react to learning about the lives and careers of diverse women mathematicians.

Study Design and Research Questions

Papert's theory of constructionism (1986) formed the theoretical framework for the study. Participants began the project with their preexisting mental constructs about mathematicians, and the intersection of race and gender on the viability of choosing mathematics as a career. Through the process of constructing dioramas about female mathematicians of different racial and ethnic backgrounds, girls could develop new ideas and understandings about women mathematicians. A key element of Constructionist theory is the importance of an authentic audience to view and critique the learning product. The school's annual Multicultural Fair was the venue for publicly displaying the girls' diorama projects to allow them to receive feedback from others.

The study employed multiple methods including qualitative and quantitative analysis of student responses to one-page questionnaires after lessons and final reflective essay writing, quantitative analysis of pretest-posttest racial identity surveys, and teacher observations to triangulate the data. The following research questions were addressed:

- 1. What aspects of a female mathematician or her life allowed students to feel a strong connection or inspiration?
- 2. How did studying the diverse, accomplished women mathematicians in an art-integrated manner affect student attitudes toward mathematics and mathematics careers.

Dioramas and Lesson Materials

Highlights of the lives and accomplishments of the six featured diverse women mathematicians are shown in Table 1. Women mathematicians were selected with the following criteria in mind: currently living, representative of different races or ethnicities, interesting mathematics career, leadership, evidence of being a caring person, and availability of several photographs on the Internet for use in dioramas and slideshows.

Table 1

Selected Highlights of Featured Women Mathematicians

Mathematician	Mathematics Career	Leadership	Social Justice Issues
Pat Courtney Gold, Native American (Craft in America, 2006-2016)	Modeled Portland air quality and Columbia River pollution; statistical analysis of storms and electric outages; translated math equations into computer code	Learned to weave traditional Wasco baskets or Sally bags that incorporate geometric designs – became master weaver	Forced to attend Bureau of Indian Affairs boarding school in kindergarten; teachers humiliated children by sniffing them and hitting them with fly swatters (personal communication)
Gloria Ford Gilmer, African American	Taught math at several colleges; worked for US Army in mathematics of exterior ballistics; research for US Department of Education	First Black woman to serve on the board of governors of the Mathematical Association of America (Riddle, 1995-2016a)	Attended a historically Black college; contributed to the field of Ethnomathematics by studying symmetry of braided hairstyles (Williams, 2008)
Ruth Gonzales, Hispanic American (Riddle, 1995-2016b)	Modeled underwater acoustics to determine submarine hiding spots; used seismic tools to find oil and gas underground; wrote computer code	Volunteered as literacy tutor at women's center and at a shelter for homeless teenagers	Parents came from Mexico and had no opportunity to attend school; Ruth and her siblings all graduated from college; Ruth collects Mexican art
Kimberly Flagg Sellers, African American (Shakil, 2010)	Associate Professor at Georgetown University focused on statistics; made graphs of positive effects of smoking cessation	Visits high schools and appears on websites to encourage students to study math; organizes math conferences for minorities	Was only African American math major in her college class and joined a sorority to make Black friends (University of Maryland, 2012).
Mary Lee Wheat Gray, White American (Riddle, 1996-2016c)	Professor of Mathematics and Statistics at American University; earned law degree so she could fight for justice through statistics court cases.	Co-founder of Association for Women in Mathematics; President of the Women's Equity Action League; involvement with Amnesty International	Was asked to leave a math society meeting because of a "gentlemen's agreement" that only [male] council members attend, she replied "I'm not a gentleman; I'm staying."
Fan Chung Graham, Asian American (O'Connor & Robertson, 2009)	Distinguished Professor at University of California San Diego; studies symmetry of Buckyballs, combinatorics, 3D graphs and how they relate to each other	Won several prizes for solving difficult unsolved problems in math; paints watercolor portraits of mathematicians	Encourages girls and women to learn math one step at a time and to appreciate that what they learn lasts; admires the accomplishments of other women in math

Table 2 shows the general sequence of lessons for the Diverse Women Mathematicians Project which was Conducted Approximately Every Other Week from October to early May.

Table 2

General Sequence of One Hour Lessons

Lesson #	Activities
1	Introductory activities, overview, distribution of diorama bases
2	Painting of diorama interior with focus on mixing colors and creating gradients
3	Painting of diorama exterior
4	Pat Courtney Gold slide show; work on cutting out and affixing mathematician's head to top of diorama
5	Gloria Ford Gilmer slide show; work on cutting out diorama images
6	Making the pop-up support for the back flap of the diorama
7	Ruth Gonzales slide show; creating the interior scenes of the diorama
8	Kimberly Flagg Sellers slide show; creating the icosahedron
9	Mary Lee Wheat Gray slide show; working on the interior pop-out scenes supported by cubes of stiff foam packing material
10	Fan Chung Graham slide show, begin work on essay
-	School's Multicultural Fair: Dioramas (without back pop-up scene or essays) are displayed
11	Live Internet video conference with Kimberly Flagg Sellers
12	Complete essay, choose images for pop-up (essays typed by researchers and images printed)
13	Finish pop-up scene and glue on essay; posttest

Each student was given a diorama base made from a medium-sized cereal box or similar cardboard food package that had been papier-mâchéd and painted with white gesso. There were four of each of the six styles corresponding to the six mathematicians. The front was cut so that the box opened like a book. Then a building or object made of cardboard was placed on the front of the box, centered over a cutout hole, so that its interior could be seen as the box was opened. An extra cardboard flap the size of the back cover was added for the pop-up scene.

Students made an icosahedron from a net of 20 equilateral triangles with attached tabs as a connection to Gloria Ford Gilmer, who served on the Board of Governors of the Mathematical Society that used this geometric shape as its symbol and also as a connection to Fan Chung Graham who worked on the symmetry of the icosahedron.

Instrumentation

Student Responses for Thematic Analysis. Students responded to one-page questionnaires after lessons in which a slide show about a mathematician was presented. Each of the six questionnaires contained four different questions drawn from the following list of questions with the first question always being asked:

- What do you admire about the woman mathematician we studied today?
- Tell something interesting, important, or surprising about this woman mathematician:
- What would you change about our Women Mathematicians Diorama Project?
- What do you enjoy the most about our project or constructing your diorama?
- Tell connections between the mathematician's life or career and your life or future career.
- Now that you know about six successful women mathematicians, which one do you feel the strongest connection to? Why? [asked after last mathematician was studied]
- Does it matter if the woman mathematician is the same race/ethnicity as you are for you to feel a strong connection? Why or why not? [after last mathematician was studied]

Essay Writing. Students were asked to write a short essay of 5 to 10 sentences about what they learned about women mathematicians through the project. These essays were word-processed and printed so that they could be glued onto the pop-up scene on the back of the diorama. The sentences of the essays were included in the thematic analysis of data that mostly consisted of student responses to questionnaires administered after lessons that included slide shows about the women mathematicians.

Additional Questions. Participants were asked two additional questions on the posttest:

- What were the three most important new ideas you learned through this project?
- What were the three best parts of the project?

Data Analysis

In the qualitative analysis, data from the post-lesson questionnaires and sentences from the reflective essays were entered onto a spreadsheet with one complete idea (usually one sentence) per line. The constant comparison method (Dye, Schatz, Rosenberg, & Coleman, 2000) was used to separate ideas into categories or themes. In this method, many lines of data were read and a category that would encompass two or more of the expressed ideas was developed and attached to those ideas in an additional column. As more lines of data were read, additional categories were developed and some categories were changed to better reflect the entirety of the data until all data were sorted into categories. In this way, the categories evolved or were continuously refined as the data were explored and constantly compared to other parts of the data. After all data and categories had been read several times and considered, then the categories were combined to form themes supported by the data in these categories. These themes were written into another column of the spreadsheet, attached to the categories supporting each theme. Then, the main ideas of each thematic category were determined from the data. The quantitative analysis of this data involved counting the number of individual data statements supporting each theme to rank the frequency of each theme's appearance. Data from other pretest-posttest or posttest questionnaires were also sorted into categories using the constant comparison method and spreadsheet function to ease sorting.

Results and Discussion

In general, students greeted the diorama construction and art work with much enthusiasm. Students expressed valuing of these new skills often and an eagerness to learn additional spatial construction skills. Example student-made dioramas are shown in Figure 1.

Figure 1. Example student-made dioramas featuring diverse women mathematicians.

Results of Thematic Data Analysis

All student responses to questionnaires and written essays were entered as 477 separate lines in a spreadsheet for sorting through constant comparison. Table 3 shows the number of student responses that were sorted into each category. The findings from these themes are summarized and illustrated with excerpts from student responses in this section.

Table 3

Themes of Student Responses to Questionnaires and Essays

Theme	Frequency
Equity, gender, and fairness issues	104
Inspirational role models	66
Mathematicians care about others	50
Persistence	39
Mathematicians love math	38
Valuing of education and knowledge	37
Math helps careers	33
Mathematicians can be social	32
Learned spatial skills	28
Valuing of hard work	27
The sports connection	21
Interesting jobs	19
Mathematicians have full lives	17
Racial and cultural diversity	16

Equity, Gender, and Fairness Issues. The most frequently-observed theme centered on equity, gender and fairness. Students observed that the women mathematicians weren't "afraid to be what they want." They mentioned many examples of how the women mathematicians promoted equity. Kimberly Flagg Sellers "started a group of women at the math conferences" for minorities in mathematics; "she was inspired to become a mathematician because she saw that very few African Americans were in math careers. She decided she would be one of the few;" “throughout her career, Kimberly has worked to increase the number of African Americans in the field of mathematics." Mary Lee Wheat Gray "stood up for what's right - she went to meetings meant only for men;" she was "kind of like Rosa Parks when she didn't want to leave the math group;" “she was using civil rights;" and "she used her math to help women have the same rights." “Pat Courtney Gold was forced to go to a Native American School with mean teachers. They whacked kids with fly swatters and wouldn’t let them speak their language;" "she couldn't get promoted because she wasn't White." "When she hit the glass ceiling she didn't give

up;" "That she found another way from the computer programming incident" (referring to her realization that she would not be promoted at her computer coding job); and "that she could do most stuff that men could do." Students unanimously commented that it doesn't matter what race or ethnicity a person is for them to feel a strong connection, for example: "Doesn't make a difference - all do great things in math regardless of color;" and "they can be whatever race and you could have a lot of connections."

Inspirational Role Models. The next-most-frequently observed theme focused on the women being inspirational role models. Students expressed that they were inspired by the lives of these women mathematicians. Students recognized that many of these women were the first or only ones to lead in mathematics and they found that especially inspiring: "Kimberly Flagg Sellers did not give up even though she was the only Black woman in math at her school [majoring in mathematics in college];" "Gloria Ford Gilmer started a new field of math called Ethnomathematics in which she studied lots of cool and weird hairstyles;" and "Ruth Gonzalez was the first Hispanic woman to get a doctoral degree in mathematics." Students noted that many of the women cared about other people becoming mathematicians. For example, Kimberly Flagg Sellers "encouraged Black women and men to become mathematicians" [through high school visits and a website] and "inspired African Americans to do math;" Fan Chung Graham "believed in other people to become mathematicians;" and Mary Lee Wheat Gray "did something about people saying girls can't do math." These comments from participants indicate the researchers were successful at informing girls about women's achievement in math and science and eliminating some stereotypes about mathematicians—two suggestions made by Hill et al. (2010) to help increase girls' interests in STEM careers.

Third Most-Frequent Theme: Mathematicians Care about Others. In contrast to the cold, empathy-lacking image many people have of mathematicians (Lawrence, 2016), students noted the caring attitude of the mathematicians they studied. Example comments from students included: “She cared for the world and not just herself; she helped others and that's what I like to do;” “I also want to change the world for the better.” Students mentioned ways they themselves were helping others such as: helping homeless people through a school program, being kind every day, helping a brother who has a broken leg, and doing a school service project for people with cancer. The fifth graders enjoyed learning about how the different mathematicians used math to help others. For example, making graphs that promoted smoking cessation (Kimberly Flagg Sellers), using statistics to bolster court cases for Amnesty International (Mary Lee Wheat Gray), teaching others to learn math (Gloria Ford Gilmer), tutoring people at youth and homeless centers (Ruth Gonzalez), using math to track and stop pollution (Pat Courtney Gold).

Persistence. Students noticed the persistence of these diverse mathematicians: "The mathematicians we learned about explored interesting things and never gave up;" "It is difficult to be a female mathematician - it takes time and interest to do good [sic] in math." Students gave examples of how the mathematicians persisted: "When Pat Courtney Gold hit the glass ceiling, she quit her job, but instead of giving up, she got a new job making baskets with animal designs." "Ruth Gonzales didn’t give up on going to school because she had no money; she [worked menial jobs] so that she could get money to go to college." "Kimberly Flagg Sellers advised us to pay attention in math to concepts because they build upon each other. It took a while for these women to get where they are today and it wasn’t easy." "I feel the strongest connection to Fan Chung because even though she broke up with her first husband, she kept going and found a new one."

Mathematicians Love Math. Students recognized the strong love of math in the women mathematicians and many identified with it: "I want to inspire people to be mathematicians. My favorite math is decimals. " Concerning Pat Courtney Gold: "I can predict that she loves math just like I do. " Concerning Mary Lee Wheat Gray "I sometimes use math when playing games or video games - she uses math and I use math".

Valuing of Education and Knowledge. Students recognized the value of education and knowledge: "Maybe [I would like a career in mathematics] because you would really have to study or know what you are doing in order to do important deeds." Students cited examples of how the women mathematicians valued education: "Mary Lee Wheat Gray went to court and when they told her that she might know math, but she didn't know the law, she went and got her law degree;" and "Ruth Gonzales had the opportunity to go to school, but her parents did not get to go to school. Her parents lived in Mexico [as children and did not have a school to attend]."

Mathematics Helps Careers. Students acknowledged the ways math helps careers: "I want to be an obstetrician and that will take a lot of school- I will have to study statistics." "Ruth Gonzales found oil underground and used math to do it." "I want to be in the Women's National Basketball Association and so you have to know angles to make baskets." As per Hill et al.'s (2010) suggestions for increasing girls' interest in STEM careers, these comments indicate that the project helped the girls understand some real-life applications of math.

Mathematicians can be Social. In alignment with Mendick et al.'s (2008) study that found the popular perception of mathematicians as people with a single-minded pursuit of mathematics, students were surprised that a math career could involve an active social life. They commented that they were surprised to learn: Kimberly Flagg Sellers "was in a sorority and I would like to know what she talked about with her friends;" and "Kimberly Flagg Sellers was the

only Black girl who was a math major, so she found a sorority club so she could stay in math." Additional example comments included: "Fan Chung Graham - that she gets to meet and connect with famous people;" and "The women mathematicians like Kimberly Flagg Sellers and Mary Lee Wheat Gray get to travel to different states and countries and talk about their work."

Learned Spatial Skills. Students enjoyed learning spatial skills such as building the pop-up back part of the diorama, the pop-out scenes supported by foam, supporting images with cardstock backing, constructing icosahedrons, and arranging cut-out images. Students commented on enjoying experimenting with color blending and making color gradients. They expressed satisfaction in seeing the completed end product with all of its intricate parts. These findings are important as spatial skills form the gateway to the STEM fields (Uttal & Cohen, 2012) and improving girls' spatial skills may foster the confidence to pursue STEM careers (Vasta et al., 1996).

Valuing Hard Work. Rather than perceiving their work as the result of mathematical genius (Mendick et al., 2008), students recognized the value of the intense effort exerted by the women mathematicians: "That she worked really hard to do this - she didn't just say that she wanted to be a mathematician [she worked hard to become one]." Pat Courtney Gold always was doing her job; that was why she was able to get another job." "Pat Courtney Gold weaved and I think that's cool because you really have to practice." "[What I admire] about Fan Chung Graham is that she takes her work seriously."

The Sports Connection. During the Internet video conference with Kimberly Flagg Sellers, Kimberly revealed that she had played sports in high school and likes to watch certain sports teams. Students murmured agreement as many of them enjoyed sports. Written evidence

for this included: “I feel the strongest connection to Kimberly Flagg Sellers because we both like math and sports;” and “Kimberly was involved in cheerleading and sports.”

Interesting Jobs. Students were fascinated with the large variety of jobs women mathematicians hold: "Ruth Gonzales studied the sea floor to find oil underground;" "I think it’s cool how Ruth Gonzales could do different experiments like that and maybe I would like to do that." Pat Courtney Gold "studied and worked in many different jobs and she wove/made baskets." "Gloria Gilmer looked at different hairstyles and saw how they had patterns. It surprised me because I did not know hair and math could go together." These comments show that this study was successful at counteracting the images found in popular culture that subordinate women’s mathematical contributions (Mendick et al., 2008) by highlighting different ways that women do math.

Mathematicians Have Full Lives. Skyping with Kimberly Flagg Sellers caused students to feel the strongest connection to her because "we got to know her more and I can connect with her now;" and "Kimberly Flagg Sellers had a boy and taught him some stuff and they played math games together. These women had other interests than math – they had full lives." Students were interested to know more about the personal lives of the mathematicians, for example: Fan Chung Graham "does math, drawing, and has time to have fun with her kids; and Fan Chung Graham "paints and married a mathematician." These examples are evidence that the girls began to understand that mathematics can be part of a happy and successful life, rather than all-consuming (Mendick et al., 2008).

Racial and Cultural Diversity. Students recognized that women mathematicians' cultures and heritages influenced their lives and math careers. Students acknowledged affinities with these women; for example, one student remarked, "I admire that she was different and liked

math just like me." Other examples of cultural connections were: Pat Courtney Gold "studied a lot of math and art. She weaved [sic] baskets like from her culture;" Ruth Gonzalez "is proud of her past so she has Mexican art"; and "Gloria Ford Gilmer was African American and she used math in African American hairstyles. There was pattern in her hairstyles."

Aspects Engendering Affinity or Admiration

Drawing from the thematic analysis of student responses, the aspects of a diverse female mathematician allowing students to feel a strong connection or inspiration can be summarized as:

- An interest in equity or fairness issues and *concern for others*, especially standing up for underdogs or doing things that help others in need;
- Being the "first" in some professional mathematical area or a trailblazer for others;
- Persisting against obstacles or through long education programs that require hard work and acquisition of knowledge;
- An intense love of, passion for, and recognized level of expertise in mathematics that is viewed as "following one's dreams;"
- Having a social life with connections to family, friends, and/or colleagues; and
- Living a "full life" with non-math interests such as art and sports or jobs that involve more than pure mathematics such as travel, helping the environment, or doing something important that society needs such as locating oil reserves.

At the end of the project, students were asked to tell specifically what they admired the most about the women mathematicians. Responses are shown in Table 4. These responses echo many of the major themes discovered from the thematic analysis, especially persistence, passion for mathematics, hard work and knowledge, following one's dreams, being a leader in the sense

of being the "first," having interesting jobs with social connections, and helping others. See Table 4. The fact that these themes recurred over different sets of responses to questionnaires confirms their importance to the students in this study.

Table 4

Aspects Participants Admired the Most about Women Mathematicians

Aspect Admired Most	Frequency		
	Minority Students	White Students	All Students
They did not give up even when things were difficult	8	7	15
The person combined art and math into a career	7	6	13
The person did what she was passionate about in a career	6	5	11
They worked hard to earn college degrees	4	7	11
They followed their dreams to their careers	4	6	10
A lot of them were the first to get a degree or the first to be on a professional committee	3	1	4
These women had knowledge and power	1	2	3
They had a lot of professional jobs and liked them all	1	1	2
They worked with important and famous people	1	1	2
Through their careers, they were able to help other people.	1	0	1

Posttest Survey Results

Students identified the most important new ideas they learned through the project as shown in Table 5. The fact that art and mathematics can be connected or integrated was identified most frequently. The observation that several of the mathematicians had interests in art (Pat Courtney Gold, Wasco basket weaver; Ruth Gonzales, collector of Ancient Mexican art; Fan Chung Graham, watercolor artist; and Gloria Ford Gilmer, analyst of the symmetry of hair designs) came as quite a surprise for many of the fifth graders. Another area of learning was past

discrimination or hardships in mathematics and how the women reacted or assumed leadership roles to alleviate these problems. Students learned what the term "glass ceiling" meant and what a historically Black college was. Students discovered that these diverse women were as proficient in mathematics as their male counterparts. They also discovered that mathematics careers can be enjoyable and involve social connections, travel, and other interests.

Table 5

The Most Important New Ideas Learned through the Project

New Idea	Frequency		
	Minority Students n = 12	White Students n = 12	All Students n = 24
Art and math can be connected	7	10	17
Women in math are sometimes treated unfairly, but they can overcome it and be successful	6	8	14
Women can do as well as men in math	7	6	13
Math can be enjoyable and cool to do	4	3	7
I learned to make a creative diorama	2	4	6
I learned to make an icosahedron	4	1	5
Women mathematicians are caring people who help others through their jobs	3	2	5
I learned how to make a gradient of color with paint	2	3	5
I learned to keep trying	0	1	1
Video games and math are connected	1	0	1

Participants' Views of Best Parts of Project

As shown in the first line of Table 7, students viewed the live, personal, video interview they had with Dr. Kimberly Flagg Sellers over the Internet as a highlight of the project. During this interview, students were able to ask their own questions and learned how Kimberly had skipped second grade, had a son with whom she played games and took on some conference trips, and that she had been a cheerleader who played several sports and liked some sports teams

in common with them. This personal connection to a mathematician with a life to which they could relate made a huge impression on them. Students often mentioned the interview as they later worked on their dioramas and spoke of Kimberly as a friend they all knew. Many students added Kimberly Flagg Sellers to their pop-up displays because of the personal connection they felt with her.

Another recurring theme was the knowledge, encouragement, and satisfaction students derived from hearing the stories of these women mathematicians and the challenges they faced and overcame. Students expressed identification with the bullying Pat Courtney Brown faced at the Indian boarding school from a mean classmate and from teachers armed with flyswatters who struck without provocation. Many identified with Ruth Gonzalez's family's poverty and how she worked menial jobs to put herself through college. Students listened carefully to challenges Mary Lee Wheat Gray faced as a woman mathematician, how she stood up to gender discrimination, and how she realized that to more effective in legal matters, she needed to be a lawyer in addition to a mathematician. They were glad to hear that she helped many suffering people through her work with Amnesty International. Students liked learning about Fan Chung Graham's challenges while learning mathematics and the prizes she won later in her career. They marveled at how Gloria Ford Gilmer started the new field of Ethnomathematics. Similarly, they enjoyed learning that Kimberly Flagg Sellers was able to solve her problem of being the only Black math major in college by obtaining friends through a Black sorority and later working to encourage more minority students to pursue mathematics. Being able to identify with the women mathematicians was an important component of the success of the project. "Often we hear from girls that it's not that they can't do math; it's that they don't identify with it. And that's critical—when you don't see yourself connected to a particular path, whether it is math-

science or motherhood, the likelihood is that you will steer clear of it" (Banaji [personal communication] cited in Hill et al., 2010, p. 77 while discussing the study by Nosek, Banaji, & Greenwald, 2002).

Table 7

The Best Part of the Diverse Women Mathematician Project

Best Part	Frequency		
	Minority Students n = 12	White Students n = 12	All Students n = 24
We were able to Skype with Kimberly Flagg Sellers	8	6	14
I was able to hear about the challenges these women faced and how they succeeded	7	6	13
We were able to paint and do creative things	3	7	10
We learned about these successful women who can be our role models	5	3	8
I was able to work with the gifted education teacher	5	1	6
I was part of a special enrichment group	1	4	5
I was released from other classes to do this project	2	3	5
I was with my friends	1	3	4
I was able to be creative and do it my way	1	1	2
We were taught by university professors	1	1	2
I enjoyed the painting and gluing a lot	1	1	2
Many of these women were from minorities and were successful in math	1	0	1

Conclusion

This complex, year-long project was well-received by students and resulted in significant new understandings of students' judgments of the appeal of a mathematics career. This section presents a summary of the most important findings, implications for classroom practice, and suggestions for future research.

Summary

Students enjoyed the project and successfully created neat, visually appealing dioramas that included essays about the diverse women mathematicians. Students placed images of themselves in the pop-up scenes of their dioramas next to images of women mathematicians from other races, suggesting that admiration crossed racial lines. Student responses to questionnaires supported the idea that students made interracial connections to the women mathematicians based on common interests or admiration.

Thematic analysis of student responses to questionnaires and of sentences from essays revealed aspects of a mathematician that allowed students to feel a connection or to feel inspired: concern for others and actions to solve equity problems; being a professional trailblazer; persisting against obstacles; passion for mathematics; having a social life with friends and family; and living a "full life" with interests such as art or sports or important mathematics-related jobs. Students identified the best part of the project as the online video conference with Kimberly Flagg Sellers because they were able to ask personal questions and discover that she led a life that reached beyond her career to family and sports, but that included exciting job-related travel opportunities. End-of-project responses to what students admired most about the women mathematicians echoed many of the ideas from the thematic analysis, including valuing of hard work and knowledge. The most frequently occurring theme was the realization that art and mathematics are connected or can be integrated. Students expressed that they derived strong motivation from integrated artwork. They identified painting and creative work as the third-most important outcome of the project.

Implications for Practice

New findings of this study concerning what attracts students to careers in mathematics included the opportunity to help others through the career, the chance to be a leader, and the importance of the career allowing one to have a full life with other interests such as art, sports, and travel. Students recognized the passion for mathematics that the studied women exhibited, their hard work and many years of education, their struggle against obstacles such as poverty and discrimination, and their persistence. These qualities need to be emphasized.

The live video interview with one of the women mathematicians was particularly salient for the girls in the study because they were able to meet and ask their own personal questions of the mathematician. Girls asked if she had a family, hobbies, and where she had traveled. The responses to their questions and the details of her life made students feel a great connection to the mathematician. Later, this mathematician seemed to dominate their essays and the girls talked about her as if they knew her. Teachers should take advantage of the affordances of technology to help students make meaningful connections to potential role models.

Suggestions for Future Research

Because the live video interview made such a strong impact on students, an interview with each of the studied women would likely have further enhanced the project. In future work, selection of potential role models could prioritize their availability for a live interview. A future study might contrast the reactions of students who do and do not participate in live interviews.

A longitudinal study of students involved in a study like the one described here, to determine if interventions like this project have a longterm impact on career choices would be enlightening.

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